EFFECTS OF DEEP TILLAGE OF SOLONETZIC SOILS ON SOIL AND CROP PARAMETERS

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INTRODUCTION

Saskatchewan has 1.5 m ha of land where solonetzic soils occur in association with grassland Chernozemic soils. Solonetzic soils are usually developed on glacial till deposits into which Cretaceous age marine shale was incorporated. They occur where artesian pressure prevents the leaching of sodium from the surface soil or it augments the supply of sodium through the movement of salts in groundwater (Anderson,1987; Pawluk, 1982).

The adverse chemical and physical properties of Solonetzic soils reduce crop productivity. The acid A horizons and dense, clayey B horizons inhibit root, water and air penetration to reduce plant growth. Deep plowing and deep ripping have been studied as methods of increasing crop yield by improving the quality of solonetzic soil for plant production (Tyurin et al, 1960; Cairns, 1962; Harker et al, 1977; Pak, 1971; Hermans, 1981; Ballantyne, 1982; Buckland and Pawluk, 1985). The effects of deep plowing and deep ripping on solonetzic soil properties and crop yield have been monitored since 1987, on plots near Weyburn in the Dark Brown soil zone and near Kerrobert in the Brown soil zone. A more complete report of the monitoring data is given in Boehm (1990).

METHODOLOGY

A schematic diagram of the research plots is given in Figure 1; site description data are given in Table 1. After site selection (1986 at Weyburn and 1987 at Kerrobert) soils were classified and sampled to provide information about soil type and variability within plot boundaries. At the Kerrobert plots, yield was also measured prior to treatment. Tillage treatments were done after harvest in 1987. Plowing was done to 60 cm using a single bottom mould board plow. Ripping was done to about 40 cm with 90 cm spacing between ripper shanks. Treatments are the same at all but the Vander Velde site, which was ripped to 30 and 40 cm, each as a treatment. This site was treated differently because it is saline, and has a relatively high water table so that the deep plowing treatment was not considered appropriate.

Neutron meter access tubes were installed at the sampling sites in spring, 1988 (Figure 1). Moisture readings were done twice per month during the growing season at the Kerrobert research plots in 1988 and 1989.

Yields were sampled using conventional harvest equipment (swather and combine) and a weigh wagon in 1989 at the Newman, Suru and Thiessen sites and in 1990 at the Newman and Vander Velde sites. Because summer fallow is included in the rotation at all of the

TABLE 1. Description of deep tillage sites.

REGION	OWNER	LOCATION	TREATMENTS
Kerrobert	Suru	SE13-33-23-W3	control, plow, rip
	Thiessen	SE01-33-26-W3	control, plow, rip
Weyburn	Newman	SE17-08-18-W2	control, plow, rip
	Vander Velde	SE34-08-18-W2	control, rip to 30 cm and rip to 40 cm

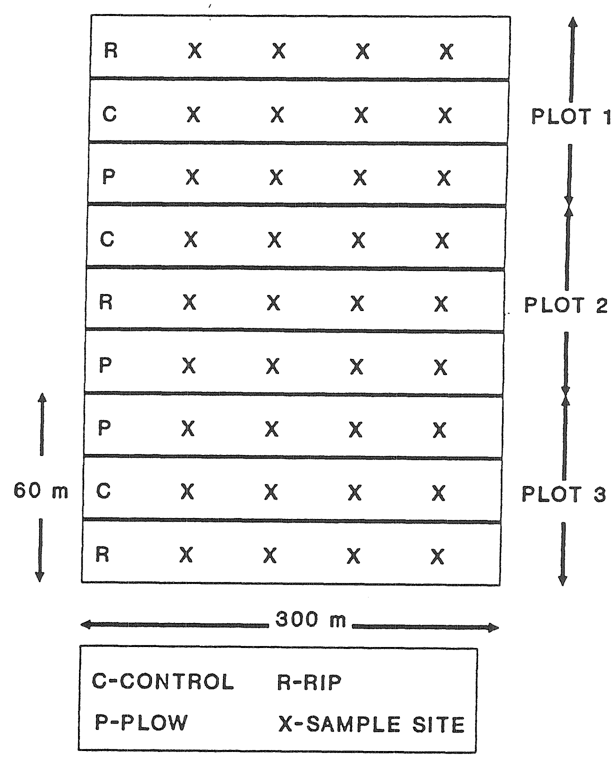

Figure 1. Schematic diagram of deep tillage plot.

sites, yield data is available only in alternate years. Using a Giddings probe, four soil samples were taken from each replicate after treatment in 1987. Soils were sampled by depth in 30 cm increments to 120 cm. Soil samples were taken in the same way from near the access tubes following harvest at all the sites in 1988 and 1989. Samples were air dried, crushed in a flail-type mill and sieved to remove the greater than 2 mm fraction. The fine earth fractions were submitted to the Soil Survey Laboratory where they were subsampled and analyzed for soluble cations, EC and pH, texture, extractable cations, organic matter content of the surface samples and mechanical analysis.

Statistical analyses were done using SYSTAT software.

RESULTS AND DISCUSSION

Yield

Yield results are given in Table 2. Before treatment in 1987, on the Suru plots, the solonetzic Chernozem soils (AdW and WwW) had higher yields than either the Solodized Solonetz (KdC) or the Solonetz soil (KhA). Yields ranged from a high of 2.7 t/ha on the Willows soils to a low of 1.3 t/ha on the Kindersley soils. On the Thiessen plots, the Solonetz (KdA) had higher yields (1.3 t/ha) than the Solodized Solonetz (0.9 t/ha)(KhA). Among the Solonetz soils at both sites, yields on the Kindersley soils were higher than on the Kettlehut soils.

Suru Site. The data for 1989 (after treatment) in Table 2 shows that at the Suru site near Kerrobert, wheat yield on the plow plots was significantly higher at 2.6 t/ha than control (1.9 t/ha) or ripped (2.3 t/ha) plot yields. Control and ripped treatments did not significantly affect yield.

Thiessen Site. There was no significant difference between treatments on the Thiessen plots, although ripping tended to increase wheat yield relative to other treatments. Yields were 1.9 t/ha on plow plots, 2.2 t/ha on control plots and 2.5 t/ha on ripped plots.

Newman Site. At the Newman site near Weyburn, the plow plot yields were higher (1.4 t/ha) than the control (1.0 t/ha) or ripped (1.2 t/ha) plot yields. This difference in yield was significant at an 85% level of probability. In 1990 grain yields were not significantly different between tillage treatments. Tillage treatment had more effect on grain yield in a year of below average precipitation (1989) than in 1990 when rainfall was more plentiful.

Vander Velde Site. At the Vander Velde site, yields were significantly higher on the plots ripped to 30 cm than on plots ripped to 40 cm. However, Table 2 shows that the R40 treatment also has the highest standard deviation of the treatments. Yields measured on the R40 treatment replicates were 1.9, 2.2 and 1.2 tonnes/ha, indicating that two of the three replicates had yields not different than the other treatments.

Moisture and Bulk Density

Table 3 shows percent moisture by volume averaged by treatment and date for the Suru and Thiessen plots in 1988, a summer fallow year, and 1989, a crop year. It also shows bulk density data collected in 1990 using a density neutron meter. Means for each date followed by different letters are significantly different at the 95% level of probability.

TABLE 2. Yields at the Suru, Thiessen, Newman and Vander Velde deep tillage projects.

OWNER/ LOCATION	YEAR	SOIL* OR TREATMENT+	N	YIELD (Tonnes/ha) X	SD	p
Suru/ Kerrobert	1987	AdW	3	2.4	0.6	
		KdC	2	1.3	0.2	
		KhA	2	1.9	0.5	
		WwW	3	2.7	0.5	
	1989	C	3	1.9	0.2	0.003
		P	3	2.6	0.3	
		R	3	2.3	0.1	
Thiessen	1987	KdA	6	1.3	0.3	
		KhC	3	0.9	0.1	
	1989	C	3	2.2	0.1	0.276
		P	2	1.9	0.8	
		R	3	2.5	0.1	
Newman/ Weyburn	1989	C	3	1.0	0.1	0.160
		P	3	1.4	0.2	
		R	3	1.2	0.2	
	1990	C	3	2.2	0.2	0.790
		P	3	2.3	0.2	
		R	3	2.3	0.1	
Vander Velde	1990	C	3	2.1	0.2	0.156
		R30	3	2.3	0.1	
		R40	3	1.8	0.4	

* Soils: AdW - Ardill solonetzic Chernozem, developed on glacial till parent material.
KdC - Kindersley Solodized Solonetz, developed on lacustrine parent material.
KhA - Kettlehut Solonetz, developed on glacial till parent material.
WwW - Willows solonetzic Chernozem, developed on lacustrine parent material.

\+ Treatments: C - Control; P - Deep plowed; R - Ripped; R30 - Ripped to 30 cm; R40 - Ripped to 40 cm

TABLE 3. Moisture and bulk density data for plots at the Suru and Thiessen sites.

DEPTH (cm)	PLOT	MOISTURE (% volume) 1988 JUNE 13	JUNE 27	JULY 13	AUG 9	AUG 22	1989 JUNE 6	JUNE 19	JULY 4	JULY 17	AUG 1	AUG 14	BULK DENSITY (g/cc) 1990
						SURU PLOTS							
0- 30	C	30C	30C	31C	33B	34B	25	25B	23B	18	16	22B	1.7
	P	18A	18A	19A	24A	24A	21	20A	18A	14	13	15A	1.6
	R	24B	25B	26B	28AB	30B	24	23AB	21AB	18	15	20B	1.6
30- 60	C	28B	28B	30B	28B	30B	30AB	30AB	29AB	27B	23B	24B	1.8B
	P	16A	16A	19A	22A	25A	23A	22A	24A	20A	18A	18A	1.6A
	R	26B	25AB	28B	28B	30B	33B	32B	31B	28B	25B	25B	1.8B
60- 90	C	28	28	30B	29B	30B	30	29	30AB	20	30	39	1.9
	P	26	24	23A	23A	24A	22	21	27A	21	21	24	1.8
	R	27	27	29B	29B	30B	33	31	32B	30	30	30	1.9
90-120	C	26	27	31	28B	29B	33	33	32	33	32	32	1.8
	P	29	27	25	19A	19A	31	27	27	21	27	22	1.8
	R	26	25	31	30B	30B	28	28	29	23	25	23	1.9
						THIESSEN PLOTS							
0- 30	C	30B	30C	31B	33B	35B	32	34B	29B	23B	20B	21B	1.7
	P	18A	16A	22A	26A	25A	30	29A	24A	19A	16A	16A	1.6
	R	23B	20B	26AB	28AB	31B	29	29A	23A	18A	16A	16A	1.6
30- 60	C	28	28	30B	28B	30	37B	37B	35B	31B	27B	27B	1.8B
	P	16	15	20A	24A	27	32A	30A	27A	23A	19A	19A	1.6A
	R	26	27	28B	28B	30	35AB	34A	33B	28B	24B	24B	1.7AB
60- 90	C	29	29	30B	30B	30B	35	35	35	33	32	32	1.8B
	P	24	24	23A	23A	25A	36	36	35	33	29	26	1.6A
	R	27	28	20A	30B	30B	35	36	35	34	32	31	1.9B
90-120	C	27	28	31	28B	29	33	33	33	29	32	25	1.9
	P	25	26	26	24A	26	35	36	35	29	28	25	1.8
	R	26	26	27	29B	31	36	32	24	24	20	24	1.9

+Treatments: C - control, P - plowed, R - ripped
*Means for each date and treatment followed by different letters are significantly different at the 95% level.

Suru Site. In 1988, the plowed plots were significantly drier from 0 to 60 cm throughout the growing season than the control or ripped plots. They also had significantly less moisture below 60 cm after August than other treatments.

The plots were seeded to wheat in 1989. Variability in moisture content within treatments increased under cropped conditions in 1989, but all trends indicated less moisture in the plow plots than in the control or ripped plots. Carry over moisture from 1988 was lower on plow plots than on the other plots, and yields were higher on the plow plots.

Bulk density was significantly lower in 1990 at 30 to 60 cm than the control or ripped treatment.

Thiessen Site. In 1988, plow plots tended to be drier than control or ripped plots. In spring, these differences were significant only in the 0-30 cm depth, but by July, significant differences were measured to 120 cm.

Wheat was grown on the plots in 1989. At the soil surface (0 to 30 cm) the control plots had significantly more moisture than the treated plots. In the 30 to 60 cm increment, the deep plowed plots were significantly drier than other plots. No significant differences occurred below 60 cm. Moisture content at all depths decreased during the growing season.

1990 data shows that plowing significantly reduced bulk density for the 30 to 60 cm and 60 to 90 cm soil increment samples compared to other treatments.

<u>Soils</u>

Soil chemical data from 1987 to 1989 are for after treatment, except for the 1986 Weyburn site data where 1986 data which was colected before treatments were done. 1986 soil samples were taken from the same locations as in 1987 to 1989 so they appear in the tables by treatment although they were taken prior to treatment and represent only background conditions.

Results of soil analyses for all sites show that variability of all of the soil properties measured is relatively high. This tends to be a characteristic of solonetzic soils which develop through active differentiation by positive and negative feedback processes. The treatments tend to randomize the variability, but the level of variability within the treated plots remains high. Because of the high level of variability of soil chemical properties, only large differences are significant. Although laboratory analyses are already the most expensive component of this project, a larger sample size would allow prediction of means within narrower limits.

Suru Site. Results of soil chemical analyses for 1987, 1988 and 1989 are given in Table 4. The data show decreases in electrical conductivity (EC), soluble Mg and soluble sodium in the 30-60 cm increment of plowed and ripped plots in 1989 compared to 1988. There is also a trend toward increased soluble sodium and EC in the 90-120 cm increment by 1989. Data in Table 4 show that for most depths exchangeable Ca and Mg values were usually significantly lower in 1989 compared to 1987. The data do not show a clear effect of treatment of soils chemistry within one year, except for the sampling done immediately after tillage in 1987. That data shows a significant decrease in EC and soluble Na in the 30-60 cm plot samples compared to the other treatments. This occurred because surface material, which has a relatively low salt content, is buried at that depth during the tillage treatments.

Thiessen Site. Soluble cations and EC (Table 5) tended to be lower (often significantly) in the 0-30 cm and 30-60 cm soil samples in 1989 than in 1987. This trend continued in the 60-90 and 90-120 cm increments for the plow plots, but values tended to increase significantly with depth on the ripped plots. Exchangeable cations Ca and Mg tended to be significantly lower to 90 cm on ripped plots in 1988 than in other years. For the 90-120 cm increments, soluble Ca and Mg decreased since 1987.

Newman Site. The soluble cation results are given in Table 6. Results show that for the plowed plots, soluble cations in the 0-30 cm increment were lower in 1986 before treatment than after treatment in 1987, 1988 or 1989. For 0-30 cm, the plowed plot data are significantly higher in all years than other results. There are no significant differences in soil samples from depths below 30 cm. On the plow plots, results show a trend of decreasing soluble cation values over time for the deeper soils increments. On the ripped plots, this trend is less evident. Exchangeable cations tend to be decreasing with time to 60 cm (Table 6) on control and ripped plots, except for exchangeable Ca and Mg in the 0-30 cm increment. Exchangeable Na was significantly lower on plow plots at 90-120 cm in 1989 than in 1986.

Vander Velde Site. In the 0 to 30 cm and 30 to 60 cm increments, significantly highest soluble Ca, Mg and Na values were measured after treatment in 1987 and 1988 and significantly lowest values were measured in 1989 (Table 7). Below 60 cm, there was a tendency for soluble cation values to decrease on ripped plots compared to control plots and over time. The same trends were evident in the exchangeable cation data shown in Table 7. The data show that exchangeable Ca, Mg and Na tended to be lower in 1989 than after treatment in 1987. They also indicate that below 60 cm, exchangeable cation content was lower on treated than control plots.

Texture data, reported previously (Boehm,1990) show that soils at the Newman plots had the highest sand content and that the Thiessen plots had a relatively high clay content. The plowing treatment tended to increase sand content of the upper horizons of the Newman plots; it tended to increase clay content of the upper horizons of the Thiessen plow plots. This reflects the sandy parent material at the Newman site and the clayey parent material of the Thiessen site. Plowing did not change the surface texture at the other sites.

Yield Regression

Results of step-wise regression analyses done with 1989 yield data on soil and moisture data are given in Table 8. At the Suru plots, the only significant equations were for the 0 to 30 cm and 30 to 60 cm depths. On the control plots, yield decreased as soluble Na increased in the 0 to 30 cm increment. At this depth, yield on plow and ripped plots varied positively with soluble Ca and

TABLE 4. Suru soil chemistry data, 1987 to 1989. *Treatments: C- control, P-plowed, R-ripped

DEPTH (cm)	YEAR	*TREATMENT	pH		E.C. (mScm)		SOLUBLE CATIONS (meq/100l) CA		MG		NA		K		EXCHANGEABLE CATIONS (meq/100g) CA		MG		NA		K	
			x	sd	x	sd	x	sd	x	sd	x	sd	x	sd	x	sd	x	sd	x	s d	x	sd
0 -30	87	C	7.2ab	0.8	1.8	1.4	5	6	6	7	11	10	0.4	0.2	11	4	10ab	2	1.7	0.9	0.3	0.3
0 -30	88	C	5.6a	3.1	1.7	2.0	5	6	7	8	10	12	0.3	0.6	10	4	9ab	3	1.3	0.9	0.4	0.4
0 -30	89	C	6.9ab	0.7	1.7	1.9	5	8	5	8	10	14	0.5	0.2	11	5	7a	2	0.6	0.5	0.2	0.2
0 -30	87	P	7.0ab	0.9	2.2	2.3	7	8	11	18	14	16	0.4	0.3	12	5	12b	4	1.4	1.0	0.4	0.4
0 -30	88	P	7.6b	0.7	47.5	18.4	12	7	16	14	26	16	0.4	0.2	11	5	9ab	5	1.3	2.0	0.6	0.6
0 -30	89	P	7.6b	0.6	1.2	1.2	3	5	3	5	7	7	0.2	0.1	13	4	10ab	3	1.1	0.9	0.2	0.2
0 -30	87	R	7.5b	0.5	10.1	14.5	11	9	16	16	23	26	0.4	0.2	13	5	12b	4	1.8	1.4	0.3	0.3
0 -30	88	R	7.1ab	0.8	2.4	2.1	7	9	8	9	15	18	0.4	0.3	9	4	11b	5	1.8	1.4	0.7	0.7
0 -30	89	R	6.8ab	0.6	2.6	5.5	4	6	10	27	21	56	0.5	0.4	10	6	8ab	2	1.0	0.9	0.3	0.3
30 -60	87	C	8.0b	0.8	6.4ab	3.0	17	10	34b	19	51ab	26	0.6	0.8	10ab	2	13ab	4	3.4	1.5	0.4	0.4
30 -60	88	C	6.4a	3.4	6.3ab	5.8	15	12	34b	30	49ab	48	0.3	0.6	9a	2	11a	4	2.7	2.0	0.3	0.3
30 -60	89	C	7.3ab	0.7	4.2ab	3.6	12	11	19ab	20	29ab	30	0.4	0.2	13b	5	11a	3	1.6	0.9	0.1	0.1
30 -60	87	P	7.5ab	0.5	3.5a	3.1	11	10	22ab	26	23a	22	0.4	0.2	13b	5	13ab	5	1.9	1.6	0.3	0.3
30 -60	88	P	7.9ab	0.4	7.8b	3.5	18	7	32b	17	57b	32	0.5	0.3	9a	4	11a	5	1.9	2.5	0.6	0.6
30 -60	89	P	7.3ab	0.6	3.1a	2.1	10	9	13a	11	20a	14	0.4	0.2	11ab	3	9a	3	1.5	0.8	0.3	0.3
30 -60	87	R	7.9ab	0.4	5.6ab	4.3	18	11	31ab	27	44ab	42	0.4	0.1	13b	4	12ab	4	2.2	1.3	0.2	0.2
30 -60	88	R	8.1b	0.3	7.0ab	3.9	17	10	32b	18	53ab	37	0.5	0.3	10ab	3	15b	5	2.8	1.4	0.5	0.5
30 -60	89	R	7.3ab	0.5	3.2a	2.2	8	8	12a	11	21a	20	0.4	0.2	11ab	5	12ab	4	2.2	1.8	0.3	0.3
60 -90	87	C	8.0	0.7	8.3	3.3	18	9	44	21	68	32	0.5	0.2	7a	3	12	3	3.7	1.5	0.4	0.4
60 -90	88	C	7.2	2.6	8.3	4.8	16	10	40	24	67	42	0.6	0.5	8a	3	11	3	3.4	1.9	0.4	0.4
60 -90	89	C	7.9	0.2	8.7	4.7	20	9	48	34	68	43	0.6	0.3	8a	3	11	4	2.7	1.0	0.1	0.1
60 -90	88	P	8.0	0.3	9.1	2.1	20	7	39	11	69	25	0.7	0.6	8a	5	10	5	2.4	2.6	0.5	0.5
60 -90	87	P	6.9	2.6	4.3	4.2	12	11	31	34	30	30	0.3	0.5	13b	5	13	3	1.8	1.3	0.4	0.4
60 -90	89	P	7.8	0.6	7.9	4.0	16	8	38	25	62	36	0.4	0.2	8a	2	11	4	2.8	1.1	0.3	0.3
60 -90	87	R	7.9	0.3	7.4	3.0	22	7	42	20	55	31	0.5	0.2	10a	4	12	4	2.7	2.1	0.2	0.2
60 -90	88	R	8.1	0.2	8.8	3.9	18	9	39	20	69	35	0.6	0.2	7a	3	10	3	2.7	1.7	0.2	0.2
60 -90	89	R	7.9	0.4	7.9	4.0	18	8	38	22	62	39	0.5	0.2	9a	2	11	4	3.0	1.9	0.1	0.1
90 -120	87	C	8.0	0.6	9.2ab	3.4	20	10	51	22	78ab	35	0.7	1.0	8a	3	11ab	3	3.3	1.4	0.4	0.4
90 -120	88	C	7.2	2.7	8.5ab	4.7	19	10	39	23	69ab	40	0.5	0.5	8a	3	10a	3	3.0	2.1	0.3	0.3
90 -120	89	C	8.0	0.1	10.7b	2.3	21	4	54	16	90b	28	0.7	0.3	7a	2	11ab	3	2.9	1.0	0.2	0.2
90 -120	87	P	7.8	0.6	6.2a	4.1	17	11	43	33	43a	33	0.6	0.6	14b	5	14b	3	1.3	2.3	0.5	0.5
90 -120	88	P	8.1	0.1	11.7b	2.3	23	1	48	11	99b	27	0.6	0.1	7a	4	9a	5	1.8	3.4	0.5	0.5
90 -120	89	P	8.0	0.2	10.9b	2.4	22	3	53	16	91b	28	0.7	0.5	8a	2	10a	3	3.1	1.3	0.4	0.4
90 -120	87	R	8.0	0.2	8.3ab	3.1	22	7	47	20	64ab	28	0.6	0.2	9a	4	11ab	4	2.5	1.4	0.1	0.1
90 -120	88	R	8.1	0.2	8.5ab	3.5	17	8	37	22	70ab	30	0.5	0.2	5a	2	9a	2	2.1	0.8	0.2	0.2
90 -120	89	R	7.9	0.1	8.6ab	3.2	17	7	38	20	72ab	31	0.6	0.2	6a	2	8a	3	2.4	1.0	0.2	0.2

TABLE 5. Thiessen soil chemistry data, 1987 to 1989.

DEPTH (cm)	YEAR	TREATMENT	pH		E.C. (mScm)		SOLUBLE CATIONS CA (meq/100l)		MG		NA		K		EXCHANGEABLE CATIONS CA (meq/100g)		MG		NA		K	
			x	sd	x	sd	x	sd	x	sd	x	sd	x	sd	x	sd	x	sd	x	sd	x	sd
0 -30	87	C	7.5ab	0.4	0.8ab	0.6	3ab	4	3ab	3	4ab	2	0.3	0.2	17ab	5	16bc	2	1.6	1.5	0.3a	0.3
0 -30	87	P	7.4ab	0.4	0.8ab	0.3	2ab	1	3ab	1	6ab	3	0.1	0.7	19b	3	18c	2	1.9	1.1	0.2a	0.2
0 -30	87	R	7.5ab	0.3	2.0ab	2.5	5ab	5	11b	18	14b	20	0.2	0.1	16ab	5	18c	4	1.9	1.7	0.2a	0.2
0 -30	88	C	7.4ab	0.4	1.3ab	0.8	5ab	8	5ab	4	7ab	4	0.3	0.2	12a	7	11b	6	1.0	1.6	0.9b	0.9
0 -30	88	P	7.7b	0.3	1.0ab	0.3	3ab	1	3ab	2	7ab	4	0.2	0.3	18ab	3	16bc	2	1.6	0.7	0.2a	0.2
0 -30	88	R	7.4ab	0.5	2.5b	2.2	8b	7	12b	13	14b	18	0.4	0.3	10a	8	9a	7	1.0	2.2	1.0b	1.0
0 -30	89	C	5.5a	3.1	0.4a	0.7	2ab	1	1a	1	2a	2	0.2	0.6	18ab	6	12b	2	0.6	0.5	0.4ab	0.4
0 -30	89	P	6.5ab	3.1	0.5a	0.6	1a	1	1a	1	3a	3	0.0	0.4	19b	3	15bc	3	1.4	1.0	0.1a	0.1
0 -30	89	R	5.8ab	3.1	0.6ab	0.8	1a	1	1a	1	4ab	4	0.2	0.4	15ab	6	14abc	3	1.2	0.9	0.3a	0.3
30 -60	87	C	8.1b	0.3	3.3ab	3.7	9ab	9	17	22	25ab	31	0.3	0.5	16b	5	19b	2	3.2	1.9	0.2a	0.2
30 -60	87	P	7.4ab	0.5	0.9a	0.2	2a	1	3	1	6a	3	0.2	0.1	18b	3	17b	3	1.7	1.2	0.2a	0.2
30 -60	87	R	8.0ab	0.2	6.4b	6.9	12ab	11	32	50	36b	45	0.2	0.1	16b	4	20b	5	2.9	2.3	0.1a	0.1
30 -60	88	C	8.1b	0.2	4.8ab	3.8	13b	11	22	21	38b	33	0.2	0.2	15b	3	18b	1	3.2	1.3	0.4a	0.4
30 -60	88	P	7.9ab	0.4	2.3ab	2.2	7ab	8	9	13	15ab	15	0.2	0.1	17b	3	18b	2	2.7	1.7	0.4a	0.4
30 -60	88	R	8.1b	0.3	5.3ab	4.5	13b	10	26	28	37b	39	0.3	0.2	8a	8	10a	11	3.2	5.6	0.9b	0.9
30 -60	89	C	6.0a	3.3	1.6ab	2.1	8ab	10	9	12	9a	10	0.5	0.5	18b	4	16ab	3	2.0	2.1	0.2a	0.2
30 -60	89	P	6.5ab	2.9	0.8a	0.8	2a	2	2	2	6a	3	0.5	0.4	18b	3	17b	2	1.8	0.5	0.2a	0.2
30 -60	89	R	6.8ab	2.5	2.9ab	3.4	7ab	8	14	19	19ab	25	0.1	0.4	16b	5	16ab	3	2.4	1.6	0.2a	0.2
60 -90	87	C	8.2	0.2	5.2ab	4.6	12ab	12	28ab	29	45ab	40	0.2ab	0.2	13b	4	20b	3	4.6b	1.9	0.3a	0.3
60 -90	87	P	7.6	0.3	1.1a	0.4	2a	1	3a	2	8a	4	0.1ab	0.6	18b	3	18b	3	2.5ab	1.3	0.1a	0.1
60 -90	87	R	8.1	0.1	5.9ab	5.2	16ab	13	42b	48	44ab	41	0.2ab	0.1	15b	5	19b	5	3.7b	2.9	0.1a	0.1
60 -90	88	C	8.1	0.2	9.0c	4.2	20b	8	45b	26	78b	44	0.4ab	0.2	13b	6	15b	4	3.5b	1.8	0.3a	0.3
60 -90	88	P	8.0	0.3	3.5ab	2.9	10ab	10	14ab	15	25a	21	0.2ab	0.1	13b	7	14b	7	2.5ab	2.3	0.7ab	0.7
60 -90	88	R	7.9	0.4	7.9b	2.7	19b	8	39b	17	59b	26	0.5b	0.3	5a	8	7a	11	1.8a	5.6	1.0b	1.0
60 -90	89	C	6.4	3.5	3.7ab	4.3	9ab	11	19ab	25	28b	31	0.0a	0.5	14b	3	19b	3	5.2b	4.0	0.2a	0.2
60 -90	89	P	6.9	3.0	2.2a	2.1	5a	7	7a	10	17a	12	0.1a	0.4	16b	3	19b	2	4.0b	1.6	0.1a	0.1
60 -90	89	R	7.2	2.6	6.2b	4.8	14ab	10	33b	30	49b	39	0.2ab	0.4	13b	4	18b	4	4.0b	2.3	0.2a	0.2
90 -120	87	C	8.0	0.4	6.8ab	4.4	19b	12	40ab	29	53ab	39	0.3ab	0.2	14ab	5	17ab	6	4.1	3.6	0.3	0.3
90 -120	87	P	7.9	0.3	1.1a	0.3	2a	1	2a	1	9a	3	0.1a	0.1	16b	4	17ab	3	2.9	1.4	0.2	0.2
90 -120	87	R	8.1	0.2	6.4b	4.9	17b	13	45b	45	51ab	41	0.2ab	0.2	19b	8	21b	4	4.5	2.6	0.1	0.1
90 -120	88	C	8.0	0.2	10.4c	3.9	24b	5	51b	23	92c	47	0.5b	0.2	12a	5	14ab	4	3.1	2.2	0.3	0.3
90 -120	88	P	8.0	0.2	5.0ab	2.3	14ab	9	21ab	13	34a	18	0.3ab	0.2	10a	7	12a	9	2.4	3.4	0.8	0.8
90 -120	88	R	8.0	0.4	9.8b	3.6	20b	6	51b	21	77b	38	0.4b	0.2	8a	6	10a	9	1.7	5.5	0.7	0.7
90 -120	89	C	6.3	3.5	5.2ab	4.6	13ab	9	28ab	23	46ab	36	0.1a	0.5	12a	5	16ab	6	5.0	4.0	0.3	0.3
90 -120	89	P	5.6	3.8	4.2a	3.4	13ab	11	22ab	18	29a	21	0.6b	0.6	13ab	4	17ab	4	4.8	3.5	1.0	1.0
90 -120	89	R	7.1	2.6	8.4b	4.7	17b	9	46b	32	67b	42	0.3ab	0.5	11a	3	17ab	5	5.9	4.0	0.3	0.3

TABLE 6. Newman soil chemistry data , 1986 to 1989

EPTH cm)	YEAR	TREATMENT*	pH		E.C. (mScm)		SOLUBLE CATIONS (meq/100l) CA		MG		NA		EXCHANGEABLE CATIONS (meq/100g) CA		MG		NA	
			x	sd	x	sd	x	sd	x	sd	x	sd	x	sd	x	sd	x	sd
-30	86	C	7.5	0.6	0.9	0.4	2a	2	2a	1	6a	4	11ab	3	6b	2	1.5b	1.1
	87	C	7.1	0.5	5.8	16.6	3a	2	3a	3	5a	8	11b	4	5b	1	0.8ab	0.6
	88	C	6.3	2.3	1.1	0.8	3a	1	2a	1	7ab	8	10ab	4	5b	2	1.0ab	1.3
	89	C	6.6	0.7	0.7	0.2	2a	1	1a	0	3a	1	8a	3	3a	1	0.3a	0.3
	86	P	7.5	0.6	1.1	1.1	2a	1	1a	1	4a	3	12b	3	6b	2	1.4b	1.1
	87	P	7.4	0.3	2.2	1.2	9b	6	6b	4	12b	9	11ab	2	6b	1	1.0ab	0.5
	88	P	7.2	0.5	3.0	2.0	14b	9	9b	6	17b	17	10ab	2	5b	1	0.8ab	0.8
	89	P	7.5	0.6	2.8	2.0	12b	10	7b	7	17b	16	13b	3	6b	2	1.2ab	0.8
	86	R	7.3	0.6	0.6	0.2	2a	1	1a	0	4a	5	12b	3	5b	1	0.9ab	0.5
	87	R	7.3	0.7	0.9	0.4	4a	5	2a	1	5a	3	12b	3	6b	2	0.8ab	0.7
	88	R	6.8	2.4	1.3	1.3	4a	2	3a	3	8ab	11	11ab	4	6b	2	0.8ab	0.7
	89	R	6.8	0.5	0.7	0.2	3a	1	2a	1	3a	2	9a	3	3a	1	0.3a	0.2
0 -60	86	C	8.2	0.6	4.3	2.9	12	11	13	12	32	27	13ab	5	8ab	2	3.0b	1.6
	87	C	7.9	0.5	3.0	2.5	10	10	10	10	23	21	15ab	5	9b	2	2.0ab	1.6
	88	C	7.6	0.6	3.6	3.9	9	9	8	11	30	38	12ab	4	7ab	3	1.7ab	1.8
	89	C	7.2	0.7	1.6	0.9	5	3	3	2	10	9	10a	3	5a	2	1.3ab	1.3
	86	P	8.1	0.5	3.2	2.7	9	10	8	8	22	21	16b	6	7ab	3	2.5ab	1.9
	87	P	7.8	0.4	1.7	1.7	6	5	5	4	11	17	13ab	3	7ab	2	1.0a	0.9
	88	P	7.7	0.6	2.4	2.8	7	9	6	10	17	23	11ab	3	7ab	2	1.4ab	1.0
	89	P	7.3	0.6	2.6	2.2	10	8	7	6	16	18	12ab	3	5a	2	1.0a	1.0
	86	R	8.1	0.6	2.1	1.8	9	11	5	5	11	11	14ab	5	6ab	2	2.2ab	1.7
	87	R	7.8	0.5	2.5	2.3	8	7	7	7	21	22	14ab	4	8ab	3	2.3ab	1.9
	88	R	7.4	2.5	3.0	3.8	9	11	10	18	22	34	13ab	6	7ab	2	1.7ab	1.3
	89	R	7.2	0.5	2.5	2.3	7	7	5	4	10	11	10a	3	5a	3	0.9a	0.7
) -90	86	C	8.2	0.3	6.6	2.8	16	9	18	10	50	23	10	3	7	2	4.2b	1.8
	87	C	8.0	0.2	5.0	3.2	15	11	18	14	41	30	11	3	8	2	3.4ab	2.3
	88	C	8.0	0.4	4.6	4.2	11	10	12	13	40	39	9	3	6	3	1.9ab	1.6
	89	C	7.6	0.6	4.4	3.6	11	9	12	12	33	31	11	5	7	3	2.2ab	2.0
	86	P	8.3	0.4	4.9	3.3	14	10	12	10	36	26	12	7	8	2	4.0b	2.5
	87	P	7.9	0.3	3.7	2.7	13	11	10	9	25	27	14	5	6	2	1.4a	1.1
	88	P	8.0	0.4	5.5	3.3	15	10	15	13	45	30	11	5	7	2	2.6ab	1.4
	89	P	7.7	0.3	3.4	3.1	9	8	7	8	26	28	12	3	6	2	2.0ab	1.8
	86	R	8.3	0.4	5.4	3.6	15	10	15	10	40	28	11	4	7	2	3.7ab	2.1
	87	R	8.0	0.3	5.1	3.4	19	12	16	12	42	35	12	6	8	2	3.2ab	2.0
	88	R	7.2	2.7	6.7	3.7	18	9	19	12	56	33	12	4	8	2	2.6ab	1.8
	89	R	7.9	0.3	4.9	3.2	12	10	13	10	37	28	10	4	7	3	2.3ab	1.5
) -120	86	C	8.2	0.2	6.1	2.4	15	8	15	10	47	20	7a	3	7	2	4.8ab	2.0
	87	C	8.1	0.1	5.9	3.5	17	10	22	15	50	30	10ab	4	8	2	3.4ab	1.8
	88	C	8.0	0.3	4.7	3.8	11	10	11	11	40	35	8a	3	6	3	3.1ab	2.8
	89	C	7.8	0.2	5.5	3.4	14	10	14	11	44	30	10ab	7	7	2	2.8ab	1.7
	86	P	8.2	0.4	6.4	3.3	16	9	16	9	49	26	9ab	4	8	2	5.2b	2.4
	87	P	8.0	0.3	5.4	2.5	21	8	16	6	44	24	14b	5	8	2	3.6ab	2.7
	88	P	8.0	0.1	7.4	3.2	19	7	19	9	65	32	8a	3	7	2	3.3ab	1.5
	89	P	7.9	0.2	5.0	3.5	14	10	10	8	39	32	11ab	4	6	2	2.4a	1.6
	86	R	8.2	0.3	6.0	3.5	15	9	15	10	46	29	8a	3	7	2	4.6ab	2.2
	87	R	8.1	0.4	5.7	3.5	20	12	18	12	49	34	11ab	6	8	2	3.5ab	1.8
	88	R	7.1	2.7	8.0	3.4	20	7	22	10	70	29	10ab	5	8	3	3.7ab	1.5
	89	R	7.9	0.3	6.7	3.4	16	9	17	9	55	30	6a	2	7	1	2.9ab	1.3

Treatment: C- control, P- plowed, R- ripped

TABLE 7. Vander Velde soil chemistry, 1986 to 1989.

DEPTH (cm)	YEAR	TREATMENT*	pH		E.C. (mScm)		SOLUBLE CATIONS CA		MG (meq/100l)		NA		EXCHANGEABLE CATIONS CA		MG (meq/100g)		NA	
			x	sd	x	sd	x	sd	x	sd	x	sd	x	sd	x	sd	x	sd
0 -30	86	C	7.1b	0.4	3.6ab	3.1	5ab	4	13ab	15	28ab	26	8	4	10b	2	3.5b	2.2
	87	C	7.3b	0.3	4.8ab	3.4	11b	5	22ab	20	35ab	31	11	3	12bc	3	2.9ab	2.2
	88	C	7.1b	0.4	4.6ab	3.9	10b	8	18ab	19	36ab	35	9	5	10b	2	2.5ab	1.8
	89	C	6.4ab	0.3	1.2a	0.6	2a	1	2a	1	7a	5	7	3	5a	3	0.8a	0.5
	86	S	6.9b	1.2	2.8ab	2.5	4ab	4	10ab	12	22ab	20	9	3	11b	2	3.3b	1.8
	87	S	7.4b	0.3	5.4b	4.0	9b	7	25ab	23	42ab	34	9	4	13c	1	2.8ab	1.4
	88	S	7.4b	0.6	6.4b	5.9	12b	8	34b	48	49b	53	9	4	11b	2	3.2b	1.9
	89	S	6.6ab	0.5	2.7ab	2.4	3a	2	7a	7	20ab	19	6	4	7a	1	1.7ab	1.0
	86	T	6.4ab	1.3	2.9ab	2.9	4ab	5	11ab	16	24ab	25	8	4	9ab	2	3.0ab	1.9
	87	T	7.2b	0.4	5.5b	3.7	11b	7	26ab	21	44b	36	10	4	12bc	2	3.3b	1.9
	88	T	5.1a	3.6	2.6ab	3.7	5ab	7	11ab	17	20ab	29	8	3	9ab	2	2.5ab	2.1
	89	T	6.4ab	0.5	1.5a	1.3	4ab	6	5a	6	7a	9	8	3	7a	2	0.9a	0.7
30 -60	86	C	8.2b	0.2	10.6b	6.6	17ab	8	64b	45	86b	60	14b	4	12ab	4	4.7ab	2.5
	87	C	8.0b	0.2	9.7ab	5.8	22b	7	56ab	42	75ab	54	13b	4	13b	3	3.5ab	1.9
	88	C	8.1b	0.2	9.2ab	6.4	16ab	9	47ab	40	78ab	59	12ab	4	13b	4	4.9b	3.4
	89	C	7.1ab	0.4	5.0a	3.4	11a	8	21a	16	35ab	28	9a	4	9a	2	2.2ab	1.4
	86	S	8.2b	0.2	8.3ab	5.3	15ab	9	44ab	34	61ab	47	13b	5	13b	2	5.2b	3.6
	87	S	8.0b	0.2	9.1ab	6.0	16ab	9	51ab	47	71ab	56	12ab	3	14b	2	3.1ab	1.6
	88	S	8.1b	0.2	10.4b	6.1	19ab	7	58b	44	84b	60	11ab	3	14b	3	4.5ab	2.4
	89	S	7.2ab	0.5	6.5ab	4.5	13ab	8	28ab	23	48ab	38	7a	4	9a	2	2.6ab	1.4
	86	T	8.2b	0.3	8.7ab	5.5	17ab	8	47ab	35	70ab	51	13b	4	12ab	3	4.5ab	2.9
	87	T	7.8b	0.3	9.5ab	5.3	22b	6	51ab	34	75ab	54	10ab	4	13b	3	4.1ab	2.4
	88	T	5.8a	3.9	5.7ab	5.8	13ab	10	26ab	29	47ab	49	13b	7	11ab	3	3.9ab	3.6
	89	T	7.1ab	0.5	4.0a	5.1	10a	9	19a	30	28a	47	12ab	4	9a	2	1.4a	1.4
60 -90	86	C	8.3b	0.3	12.3	6.9	19	8	75	53	98	63	14	5	10	4	5.0b	2.7
	87	C	8.0b	0.2	10.9	5.6	22	7	61	45	88	55	14	5	14	2	4.0ab	1.6
	88	C	8.1b	0.2	11.4	4.4	22	1	56	31	97	46	12	4	12	2	4.2ab	1.4
	89	C	7.9b	0.2	10.7	5.7	20	5	60	38	83	57	10	3	12	3	3.3ab	1.8
	86	S	8.2b	0.2	9.7	5.7	17	8	51	39	77	51	12	4	13	2	5.3b	2.1
	87	S	8.0b	0.2	10.1	5.5	20	8	57	49	78	60	13	5	13	2	2.8ab	1.5
	88	S	8.0b	0.4	10.3	5.4	18	7	55	37	83	52	12	6	13	2	4.8ab	2.9
	89	S	7.7b	0.5	9.7	5.7	17	9	51	40	76	53	9	4	12	2	3.8ab	1.6
	86	T	8.2b	0.3	10.6	5.4	22	1	61	41	85	56	13	4	11	3	4.5ab	2.7
	87	T	7.9b	0.2	9.3	5.3	21	6	49	31	73	56	10	3	12	3	3.7ab	2.6
	88	T	5.8a	3.9	6.7	6.0	15	10	32	30	55	52	11	5	12	4	4.3ab	4.4
	89	T	7.6b	0.2	6.5	5.7	20	9	35	34	43	56	13	6	11	3	1.7a	1.9
90 -120	86	C	8.2b	0.2	12.4	4.9	22ab	2	67	40	99	51	12	4	11ab	4	5.3b	2.0
	87	C	7.9b	0.1	11.7	4.2	25b	1	63	34	94	43	12	3	13b	2	4.2ab	1.3
	88	C	8.0b	0.1	12.3	4.2	22ab	1	57	35	99	46	10	3	12b	2	4.7b	1.3
	89	C	8.0b	0.2	12.6	5.2	22ab	2	69	40	99	53	8	3	12b	2	3.8ab	1.5
	86	S	8.1b	0.2	9.6	4.6	19ab	6	46	28	76	45	9	4	12b	2	5.3b	2.0
	87	S	7.9b	0.3	10.2	5.9	24b	2	64	50	85	62	13	4	13b	2	3.3ab	2.1
	88	S	8.0b	0.2	10.3	5.5	20a	5	53	39	80	52	10	6	11ab	2	4.2ab	2.0
	89	S	7.9b	0.2	11.3	4.8	21ab	4	59	32	90	48	9	3	11ab	2	3.5ab	1.4
	86	T	8.1b	0.3	10.3	5.3	23ab	2	56	38	81	55	13	5	10ab	3	4.5b	2.7
	87	T	7.8b	0.3	9.7	5.4	22ab	4	51	33	77	60	10	3	12b	2	3.7ab	2.2
	88	T	6.1a	3.4	8.0	5.5	18a	9	36	26	67	50	13	3	10ab	2	4.6b	3.1
	89	T	7.6b	0.2	6.8	5.5	20a	9	34	32	47	53	10	7	9a	5	1.5a	2.5

*Treatment: C- control, P-plowed, R-ripped negatively with soluble Mg and/or exchangeable Na. On the plow plots, yield also decreased as exchangeable Na in the 30 to 60 cm sample increased.

At the Thiessen plots, no significant equations were derived for the plow plots at any depth. On the control plots, yield varied negatively with soluble Na and with soluble and/or exchangeable Ca at all depths. Yield varied positively with Mg in the 60 to 90 cm increment. Yield on the ripped plots was positively correlated with soluble Mg at 0 to 30 cm, to June 6 moisture at 60 to 90 cm and to August 1 moisture at 90 to 120 cm.

TABLE 8. Regression equations: yield on 1989 soil and moisture data.

DEPTH (cm)	TREATMENT*	R^2	EQUATION	p
			SURU PLOTS	
0- 30	C	.42	YIELD= 1131 - 6(SOLUBLE SODIUM)	0.03
	P	.60	YIELD= 1205 + 14(SOLUBLE CALCIUM) - 4(SOLUBLE MAGNESIUM)	0.05
	R	.71	YIELD= 1220 - 24(EXCHANGEABLE SODIUM) + 15(SOLUBLE CALCIUM)	0.05
30- 60	P	.81	YIELD= 1284 - 133(EXCHANGEABLE SODIUM)	0.01
			THIESSEN PLOTS	
0- 30	C	.50	YIELD= 371 - 5(SOLUBLE SODIUM)	0.03
60- 90	C	.89	YIELD= 374 - 5(SOLUBLE CALCIUM) + 3(SOLUBLE MAGNESIU) - 1(SOLUBLE SODIUM)	0.003
	R	.96	YIELD= 468 + 26(JUNE 6 MOISTURE)	0.001
90-120	C	.90	YIELD= 412 - 0.4(SOLUBLE SODIUM) - 3(EXCHANGEABLE CALCIUM)	0.01
	R	.65	YIELD= 389 + 1(AUGUST 1 MOISTURE)	0.01
			NEWMAN PLOTS	
0- 30	R	.58	YIELD= 1513 - 576(SOLUBLE POTASSIUM)	0.004
30- 60	R	.61	YIELD= 1372 - 570(SOLUBLE POTASSIUM)	0.003
60- 90	C	.70	YIELD= 1601 - 36(SOLUBLE SODIUM) - 51(EXCHANGEABLE CALCIUDM)	0.02
	P	.84	YIELD= -1775 + 440(ph) + 23(SOLUBLE CALCIUM) -1447(SOLUBLE POTASSIUM)	0.002
	R	.54	YIELD= -1841 + 418(pH) - 533(EXCHANGEABLE POTASSIUM)	0.03
90-120	C	.57	YIELD= 1195 - 203(EXCHANGEABLE SODIUM)	0.01

* Treatment: C-control, P=plowed, R-ripped

Data for the Newman site is given in Table 8. For the 0 to 30 cm and 30 to 60 cm depths, yield on the ripped plots was negatively correlated with K. Correlation data of Newman site soil properties showed that soluble K is highly correlated to percent clay. At this site, the soils with the highest clay content are the solonetzic soils indicating that yield is varying as a function of solonetzic development. Regression equations for control plots yields were significant only for depths below 60 cm. Yield varied negatively with soluble Na and exchangeable Ca in the 60 to 90 cm soils samples and with exchangeable Ca in the 90 to 120 cm samples. On the plowed plots, yield regressions were significant only on the 60 to 90 m data. The equation indicates that yield varied upward with pH and soluble Ca but negatively with soluble K, indicating that yield varied with clay content.

CONCLUSIONS

The largest significant effects of treatment on yield occurred on the plowed plots in the 1989 at the Newman site (40%) and at the Suru site (36%). At these sites, ripped plot yields where 20 % greater than control plot yields. This suggests that the effect of tillage treatment on yield was greatest in years of moisture limitation compared to more normal years. The moisture data shows that at Kerrobert, the plow plots tended to be drier, especially within the root zone, than other treatments. This suggests that crops may be able to exploit the B horizon for moisture more thoroughly than on other plots. Treatment has had the least effect on yield at the two sites (Thiessen and Vander Velde) with the greatest proportion of clayey, saline and sodic parent materials where it is likely that the soil environment still favours development of solonetzic soils. Treatment may be most effective on soils which have begun to degrade.

Results of soil analyses show a trend of decreasing soluble cations in the upper horizons of the plowed and ripped plots. There tends to be a corresponding increase in soluble cations in the 90-120 cm sample of the treated plots.

Moisture has been monitored on the Suru and Thiessen plots since 1988. At both sites, the plow plots tend to be drier than control or ripped plots in both 1988 and 1989. This suggests that the plow treatment, which brought subsoil material to the surface, caused the loss of stored subsoil moisture which has not been recharged by 1989. Relatively high yields on plow plots at some sites may also result in relatively low moisture within the root zone.

Yield results were regressed against soil and moisture data. The regression equations are variable, but tend to show a negative correlation to Na in the upper sampling increments.

After only one or two harvests at each site, it is not possible to make conclusions about the effects of treatment on crop yield. The plots will be monitored in 1991 with financing provided by the Agriculture Development Fund.

ACKNOWLEDGEMENTS

I thank the Prairie Farm Rehabilitation Administration for financial, professional and technical support. I also gratefully acknowledge others who helped with this project, namely, R. Nashiem, D. Brock, M. Foster, P. Krug, B. McCann and T. Nerbas.

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